Black start restoration study analysis solutions

At glance

The occurrence of a massive power outage that includes the complete loss of generation, load and the transmission network serving the system load requires the use of selected generating stations with self-starting capability (black start units) to get the system back into operation. These black start generating units usually can only supply a small fraction of the system. Thus, they need to be used to assist in the starting of larger units or black-started units, which need their station service loads to be supplied from outside power. Only when these larger units can come online can full restoration of system load occur. Thus, a restoration plan following a system blackout includes small combustion turbines or hydro turbines that can be used to black start large steam driven plants located electrically close to these black-starting units.

The typical black-starting scenario includes the self-starting unit(s), the transmission lines or cranking path that will transport the power supplied to the large motor loads in the power plant to be black-started, and transformer units. The transformer units would include the generator step-up transformers of the black start generating unit and the steam turbine unit involved one or more auxiliary transformers at the steam plant and power transformers to step-down or step-up the voltage in the cranking path. The transmission lines used for the black start may be either overhead or high voltage underground cables. The load to be black-started includes system load along the cranking path and at the plant(s) to be black-started, very large induction motors ranging from a few hundred HP to several thousand HP, plant lighting and small motor load.

The black start plan describes the steps that the transmission operators need to take to restore the isolated power system from the black start unit(s), sequentially energizing transformers, transmission lines, and potentially shunt compensation and load pickup, to supply power to the steam unit auxiliary loads to allow that unit to begin operation.

Our solution

The purpose of a black start study is to verify the feasibility of a black start plan in terms of both steady state and transient operating conditions. Siemens Power Technologies International (Siemens PTI) has performed several such black start analyses for large interconnections, large city systems and rural electric cooperatives. The following describes the recommended steady state analysis of an isolated power system:

- Voltage control and steady state overvoltage (Ferranti effect) analysis.
- Capability of the black-starting units to absorb vars produced by the transmission system used in the cranking path.
- Step-by-step simulation of the black start plan being tested to ensure its viability and compliance with required operational limits.
- Verification of the robustness of the tested black start plan to ensure its ability to compensate for the unavailability of key components to be used in the plan.
- Generation and load matching.

Voltage control analysis determines the black-starting generating unit AVR's voltage reference set-point and off-nominal tap setting for all transformers that are part of the plan. This will ensure proper control of voltage in the cranking path(s) and that the plan will provide the needed terminal voltage to start the large induction motor loads at a black-started plant. The receiving end bus voltage of the transmission line(s) is estimated when the black-starting unit energizes the unloaded generator step-up transformer and transmission line(s). The charging current generated by the transmission system of the cranking path will be monitored to estimate the reactive power absorbed by the black-starting unit which may lead to self excitation of the black start unit in extreme cases.

In summary, the step-by-step steady state simulation of the black start plan will be important to verify its robustness to a loss of a system component in its cranking path and its compliance to required operational limits on voltage and power flows.

Upon completion of the steady state analysis, the dynamic analysis begins from an initial steady state operating point representing the first step in the cranking path of the restoration plan. Elements of the dynamic analysis of the black start plan may include some or all of the following:

- Load-frequency control
- Voltage control
- Load rejection – voltage and frequency dynamics
- Self-excitation assessment
- Cold load pick-up – voltage and frequency dynamics
- Large induction motor starting and acceleration time to reach rated speed
- Motor starting sequence assessment
- System stability

The dynamic analysis of the electrical island created by the cranking path includes the simulation of the start up of large induction motor load, such as boiler feed-water pumps and draft fans, used by the unit to be started, and assessment of the load-frequency response observed during that start-up. The frequency dip and recovery produced by the start up of the largest motor or system load rejection is one of the results sought from the analysis. The frequency dip is used to ensure that tripping of the black-starting unit by under-frequency protection does not occur. The frequency and voltage recovery response might also help in the selection of the most technically viable motor starting sequence.

For more information

Contact Siemens PTI consulting sales at +1-518-395-5000 or send an email to: ***pti-consulting.ptd@siemens.com***.

Siemens Industry, Inc.
Siemens Power Technologies International
400 State Street
P.O. Box 1058
Schenectady, NY 12301-1058 USA